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(54) **Helmet position measurement system**

(57) A helmet position measuring system comprises three illuminating and sensing units 4, 5 mounted at fixed positions in the cockpit and at least three retro reflectors 2A, 2B, 2C on the pilot's helmet, each illuminating and sensing unit being arranged to track a separate one of the retro reflectors and supply data giving the bearing of the retro reflector to a calculating device 13.

Each sensing and illuminating unit contains an infra red source and an infra red sensor having narrow bore sighted fields of view. By measuring the angular position of a separate one of the retro-reflectors from each of the sensing and illuminating units the position and orientation of the helmet can be calculated trigonometrically.

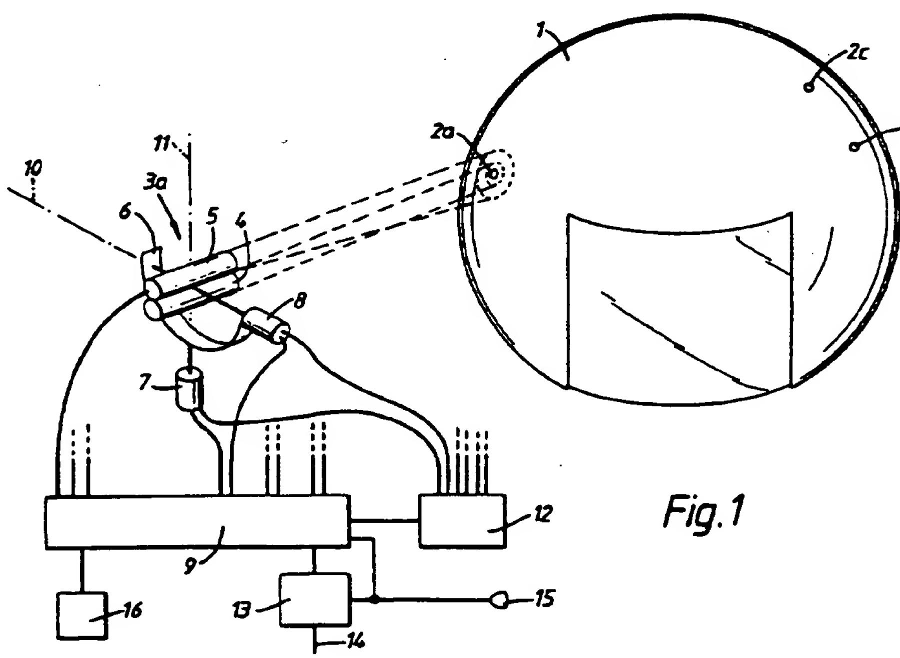

Fig.1

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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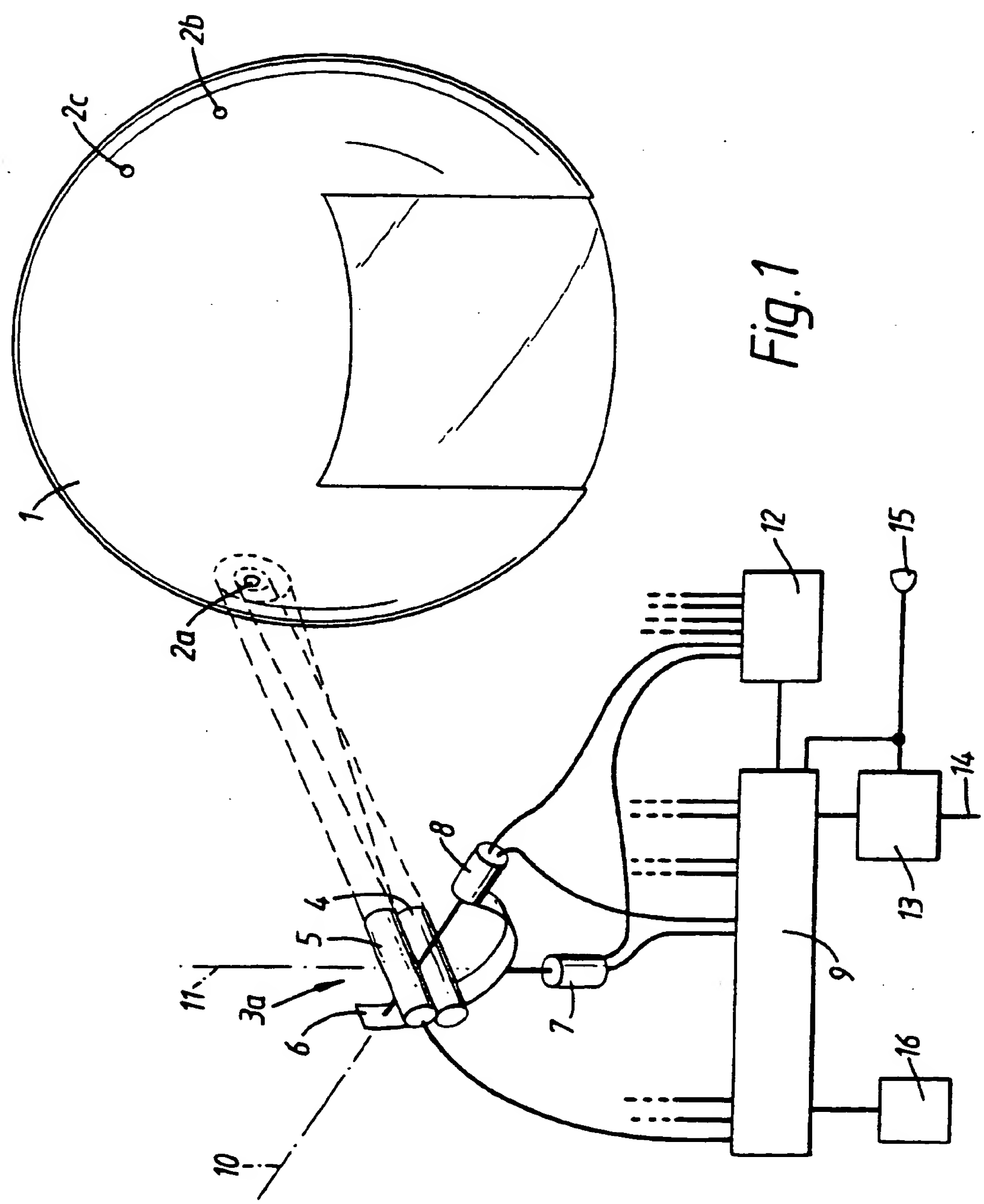

Fig.1

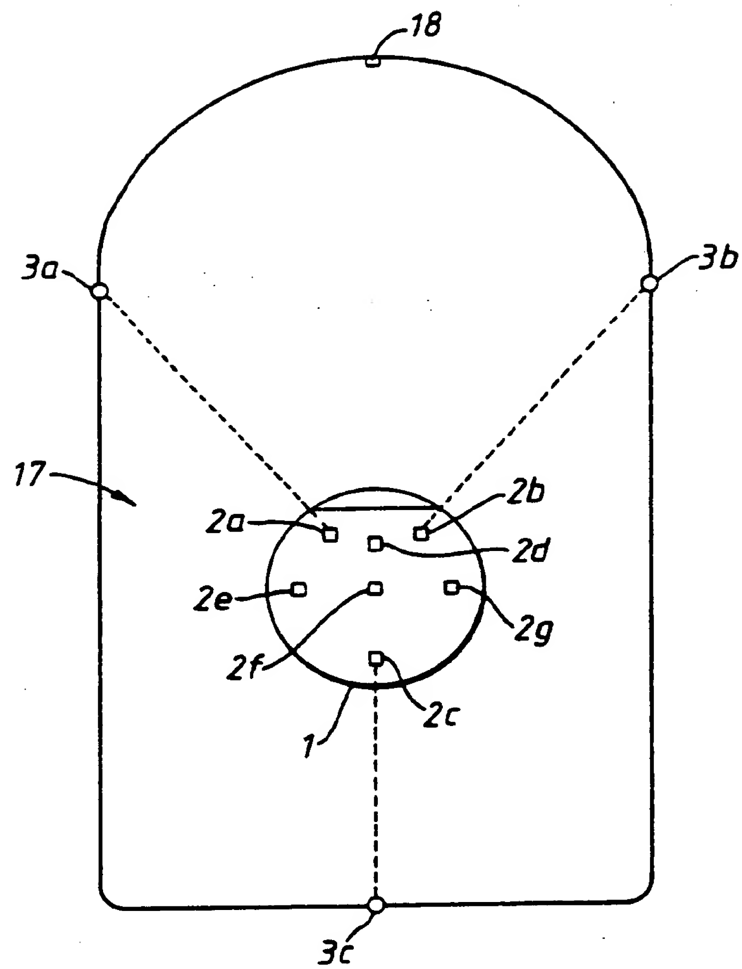

Fig. 2

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Helmet Position Measurement System

This invention relates to a helmet position measurement system and particularly to a helmet position measurement system for use in an aircraft cockpit.

In modern aircraft cockpits numerous avionic systems are used such as visor mounted head-up displays which can only function if the position and orientation of the pilots head can be accurately sensed. It can generally be assumed that the helmet is rigidly mounted on the pilots head so that the position and direction of pointing of the pilots head and helmet are always the same.

Typically where a helmet mounted display is used in addition to a head-up display (HUD) the pointing direction of the helmet needs to be measured to an accuracy of better than 6 miliradians. Where the helmet mounted display (HMD) only is used a pointing accuracy of between 0.1 and 1 miliradian is required.

One way of obtaining this accuracy is to mounted to plurality of light emitting diodes emitting infra-red radiation and modulated at different frequencies on the

pilots helmet and observing these using a wide angle lens, the position and orientation of the helmet can be deduced from the relative positions of the LED's in the field of view of the wide angle lens.

Such systems suffer from a number of problems which have made them unsatisfactory in practice, the first problem is that aircraft cockpits generally contain large numbers of shiny surfaces and as a result reflected light from the diodes can be received by the sensor as well as light coming directly from the diode, since there is no way of telling which of the two apparent light sources is the real diode this results in the system becoming confused as to the positional orientation of the helmet due to this ambiguity. A further problem is that if the sun enters the field of view of the wide angle sensor it can drown out the infra-red signal from the diodes. It has been attempted to overcome this problem by using matched filters on the diodes and sensor but the sun is so bright over such a large range of frequencies that this has not been successful. Thirdly the need to place relatively powerful LED's on the helmet is very inconvenient, firstly because on a combat aircraft are designed to maneuver at high peak accelerations it is very important to keep helmet masses as low as possible to reduce the loads on the pilot's neck and as a result the weight of

the diodes and associated wiring is undesirable, secondly it is difficult to dispose of the heat generated by the diodes on the helmet because of their position on top of the pilots head furthermore the diodes must be pulsed so that the different diodes can be identified by the sensor and the switching on and off of the diodes can generate undesirable electromagnetic interference (E.M.I.) within the cockpit.

Finally the lights generated by the LED's can pass out of the cockpit and be used by other aircraft to detect and track the aircraft, which is clearly undesirable in any military application.

There is a further basic problem which arises from the optical geometry of the system and this that the infra-red sensor must have field of view wide enough to cover a relatively large volume within the cockpit and must be quite near to this volume because of the requirement to place it within the cockpit and as a result the optical system employed must be a wide angle lens. As a result the separation at the infra-red sensor of the images of diode positions separated by small angles is very small and this limits the accuracy with which the direction of the diodes from the sensor can be measured. As a result it is difficult to produce a system with the required pointing

accuracy.

This invention was intended to provide a helmet tracking system overcoming these problems at least in part.

This invention provides a helmet position measurement system comprising three illuminating and sensing units mounted at fixed positions relative to an aircraft cockpit and three retro reflectors mounted at fixed positions on a helmet, each of the illuminating and sensing units being arranged to track a separate one of the retro reflectors by emitting light which is reflected from the retro reflector back to the unit and to supply data giving the bearing from each of the units to its respective retro reflector to a position and orientation calculating device whic calculates the position and orientations of the helmet from this bearing data.

Placing the light sources at a fixed position on the aircraft and placing only retro reflectors on the helmet allows the mass of the helmet to be reduced because retro reflectors can be made very light and also eliminates the need for any wiring to be linked to the helmet as part of the helmet position sensing system. Furthermore, with the elimination of all active elements from the helmet the

problems of heat dissipation and E.M.I. are reduced because it is much simpler to shield and arrange heat sinks for elements fixed to the aircraft than it is for elements mounted on the helmet.

Preferably each illuminating and sensing unit has a field of view comprising only a part of the helmet and moves this field of view to track its respective retro reflector. This reduction in the field of view of the sensor removes the need to employ a wide angle lens and as a result movements of the retro reflector relative to the sensor will produce relatively large and easily measured movements in the image, allowing the required pointing accuracy for the system to be obtained. Furthermore the reduced field of view of the sensor reduces the problems produced by external light sources and extraneous reflections by reducing the chances that such an external light source or reflection will fall within the field of view of the sensor.

Advantageously each illuminating and sensing unit has a field of illumination comprising only a part of the cockpit which is within its field of view. This further reduces the problem of extraneous reflections because each light source is emitting in a smaller range of directions and as a result the chances of light from the light source

bouncing off a reflective surface and back to one of the sensors is reduced. More importantly the power of the light source may be greatly reduced because it only has to illuminate a smaller area, and because a wide angle lens is no longer used on the sensor, the intensity of illumination required within this reduced area is lower than before. This allows a compounded reduction in the required illuminating power. Finally as a result of this reduction in overall illuminating power and the fact that each light source emits over a smaller range of angles the chances of light escaping the cockpit and being picked up by another aircraft is greatly reduced.

Helmet position measurement systems embodying the invention will now be described by way of example only with reference to the accompanying figures in which;

Figure 1 shows a first helmet position measurement system employing the invention; and

Figure 2 shows a second helmet position measurement system employing the invention, similar parts having the same reference numerals throughout.

Referring to Figure 1 a pilots helmet 1 is shown, this

is mounted on a pilots head and is situated within an aircraft cockpit, but for simplicity only the helmet 1 is shown.

The helmet 1 mounts three retro reflectors 2a, 2b and 2c. The retro reflectors 2a, 2b and 2c are each formed by a small area of metalised corner cube elements formed from the basic plastic material of the helmet 1, other forms of retro-reflector such as spun glass 'cats eyes' could be used instead. As is well known retro reflectors reflect incident radiation back to its source.

Each retro reflector 2a, 2b and 2c has an associated illuminating and sensing system 3a, 3b and 3c. Each illuminating and sensing system 3 comprises a collimated infra-red radiation source 4 and an infra-red sensor 5. The infra-radiation source 4 and the sensor 5 include optics arranged so that the infra-red emitter 4 having a field of illumination arranged so that it emits a beam of infra-red radiation slightly larger in cross section than the area of each of the retro reflectors 2 throughout the range of possible positions of the helmet 1. The infra-red sensor 5 is boresighted parallel to the infra-red illuminator 4 and the infra-red sensor 5 has a slightly larger field of view than the field of illumination of the infra-red illuminator

4, so that anything illuminated by the infra-red beam 4 will always be within the field of view of the infra-red sensor 5.

Only one of the illuminating and sensing systems 3 is shown, the unit 3a associated with the retro reflector 2a.

The infra-red transmitter 4 and receiver 5 are mounted in gimbals 6 and their position about a vertical axis 11 is controlled by a first motor 7 while their position about a horizontal axis 10 intersecting the vertical axis 11 is controlled by a second motor 8.

The infra-red sensor 5 contains a point sensing detector (PSD) element which produces an output giving the X and Y co-ordinates of the illuminated retro reflector 2a within the field of view of the sensor 5. Unlike a conventional sensor which produces an output giving the amount of radiation received from each point in the field of view a PSD output simply gives the X and Y co-ordinates on the sensor element of the centroid of the radiation pattern falling on the element. Provided only a single point radiation source is present within the field of view of the sensor this will give a very accurate measure of the direction of the radiation source relative to the boresight

direction of the sensor, but if there is more than one radiation source present the sensor will give as an output the centroid of both of them and as a result the directional information produced will be useless. Thus the sizes of the fields of view of the sensors 5 and the separation of the retro reflectors 2 must be arranged so there is no possibility of more than one of the retro reflectors 2 simultaneously lying within the field of view of any one of the sensors 5.

The motors 7 and 8 also include angle sensors which give an output indicating the angular position of the illuminator 4 and sensor 5 about their respective pair of axes 10 and 11. The data from the motors 7 and 8 and the output data from the sensor 5 are supplied to a processor 9. The processor 9 calculates from this data the bearing of the retro reflector 2a about the axes 10 and 11 from their point of intersection and also calculates the position of the retro reflector 2a within the field of view of the sensor 5 and the movements of the sensor 5 about the axes 10 and 11 required to bring the retro reflector 2a into the centre of the field of view of the sensor 5.

In order to simplify these calculations the optics of the sensor 5 are arranged so that the amount of linear

movement of the image in the image plane of the sensor 5 is directly proportional to angular movement of the retro reflector 2A about the axes 10 and 11.

The processor 9 then passes instructions to a motor controller 12 informing it of the necessary movements of the motors 7 and 8 to bring the retro reflector 2a to the centre of the field of view of the sensor 5, simultaneously the processor 9 passes the bearing of the retro reflector 2a to a position and orientation calculation unit 13.

In addition to controlling and sensing the positions of the retro reflector 2a and associated sensor 3a the processor 9 and controller 12 also senses the position and orientation of retro reflectors 2b and 2c using associated illuminating and sensing systems 3b and 3c respectively. The position and orientation calculation unit 13 is supplied with data by the processor 9 giving the direction of the retro reflectors 2a, 2b and 2c from their respective sensors 3a, 3b and 3c and the unit 13 calculates from this the position and orientation of the helmet 1.

Geometrically there is a degree of ambiguity where three sensors each provide bearing to one of three retro reflectors in terms of pure geometry there are two possible

positions in which the helmet could be and these cannot be resolved. However in a practical system this ambiguity does not arise because the retro reflectors 2 are not visible to the sensors 5 through a full sphere because of the line of sight between retro reflector 2 and sensor 5 being blocked by the helmet 1. The ambiguity would only arise if one or more of the retro reflectors 2 were visible to their respective sensors 5 from two diametrically opposed positions relative to retro reflector 2. This will of course not be the case in a real system because the retro reflector 2 will not reflect over a sufficiently large range of angles for this to occur and in any event the body of the helmet 1 will block at least one of the two diametrically opposed lines of sight.

The position and orientation of the helmet 1 calculated by the position and orientation calculation unit 13 is supplied along a line 14 to other parts of the aircrafts avionics systems such as the systems generating images for the head-up display system.

The retro reflectors 2 are purely passive devices and as a result it is not possible for the illuminating sensing system 3 to tell which of the retro reflectors 2 it is observing at any given time, in order to prevent this

resulting in any ambiguity as to the position of the helmet 1 the system must be initialised when the pilot first enters the aircraft by his placing his head, and thus the helmet 1, in the pre-arranged position and pressing a button 15 which informs the processor 9 that the pilot is in the cockpit in the initialisation position. In response to this signal from the button 15 the processor 9 moves from a memory 16 the bearings of the retro reflectors 2a, 2b, 2c from the illuminating and sensing systems 3a, 3b and 3c and instructs the motor controller 12 to move the sensing and illuminating units 3 onto these bearings. Although it is unlikely that the pilot will be able to control his position precisely enough to put the retro reflectors 2a, 2b and 2c exactly in the centres of the fields of view of their respective sensing and illuminating units each of the sensing illuminating units 3 will have one and only one of the retro reflectors 2 in its field of view. If necessary the motor controller 12 could be arranged to cause each scanning and sensing unit 3 to scan a small area on initialisation centred on the expected position of its respective retro reflector 2 so as to ensure that the retro reflector 2 is detected.

It will be realised that the possible range of movements of a pilots head are sufficient that wherever the

three retro reflectors 2 shown in figure 1 are placed on the helmet 1 and wherever the illuminator and scanner unit 3 are situated within the cockpit it will be possible for the pilot to move such that at least one of the sensors 3 no longer has the line of sight to its respective retro reflector 2. In order to overcome this problem a more realistic system is shown schematically in figure 2 in plan view.

The helmet 1 on the pilots head is situated within the cockpit 17 with three illuminating and sensing units 3a, 3b and 3c spaced apart around the perimeter of the cockpit. The helmet 1 bears three retro reflectors 2a, 2b and 2c each of which is within the field view, on initialisation of the system, of a respective one of the illuminating and sensing units 3a, 3b and 3c. As explained above as the pilot moves the illuminating and sensing units 3 are controlled so that each tracks its respective retro reflector 2a, 2b and 2c as the helmet 1 moves around.

The helmet 1 also bears further retro reflectors 2d to 2g, the retro reflectors 2a to 2g being positioned on the helmet 1 so that whatever the position and orientation of the helmet 1 within the cockpit 17 each of the illuminating and sensing units 3 can track a different one of the retro

reflectors 2. That is to say not only must each illuminating and sensing unit 3 be able to see a retro reflector 2 but also each illuminating and sensing unit 3 must have a retro reflector 2 within its field of view which is not the only retro reflector 2 within the field of view of another of the units 3. The field of view in this case being the entire volume of space which can be viewed by the illuminating and sensing unit 3 as it is moved about the axes 10 and 11 rather than the much smaller field of view of the sensor 5 itself.

The memory 16 associated with the control unit 9 contains information identifying which retro reflector 2 should be tracked by which illuminating and sensing unit 3 for each position and orientation of the helmet 1. Obviously it would require a very large amount of memory to store this data for each possible position and orientation of the helmet 1 so this information is stored in the format of a look up table identifying which illuminating and sensing unit 3 tracks which retro reflector 2 for each range of positions and orientations of the helmet 1 for which this tracking solution is acceptable.

When the helmet moves in orientation and position into an orientation and position where one of the retro

reflectors 2 being tracked is about to move out of the field of view of its respective illuminating and sensing unit 3 the control unit 9 designates another retro reflector 2 which is not about to move out of the field of view of that illuminating and sensing unit 3 and supplies the bearing of this retro reflector 2 from the illuminating and sensing unit 3 to the motor controller 12 which moves the illuminating and sensing unit 3 so that the new designated retro reflector 2 is within the field of view of its respective sensor 5.

One potential problem with this system is that if the field of view of the sensor 5 of one of the illuminating and sensing units 3 can see outside the cockpit 17 it may see the sun or some other external infra red source. This will of course render the bearing information derived from its centroid tracker entirely useless. In order to prevent this happening the memory 16 also includes helmet position and orientation combinations which would result in the field of view of one of the sensors 5 being able to see out of the cockpit 17. The control unit 9 can change the appropriate illuminating and sensing unit 3 to tracking a different one of the retro reflectors 2 so as to avoid the sensor 5 being able to see out of the cockpit 17. Since the field of view of the sensor 5 is always greater than the field of

illumination of the illuminator 4 this will also prevent infra red radiation being emitted out of the cockpit directly from any of the infra red illuminators 4.

The system described above is initialised by placing the helmet in a known position, it would be possible instead to initially operate the illuminating and sensing units 3 in a scanning mode in which they each scan their entire field of view and the unit 9 calculated the bearings to every retro reflector in that field of view, the approximate position and the orientation of the helmet 1 could then be calculated from this data so that each of the sensing and illuminating units 3 could be allocated a specific one of the retro reflectors 2 to track. The position and orientation of the helmet 1 could then be more accurately defined as tracking continued.

In order to allow any pointing errors in the illuminating and sensing units 3 to be corrected a reference retro reflector 18 at a fixed point in the cockpit 17 is provided and the control unit 9 programmed to move each of the illuminating and sensing units 3 to point at this fixed retro reflector periodically to check that they are pointing in the correct direction. By comparing the known bearing of this reference retro reflector 18 with the bearing sensed by

each illuminating and sensing unit 3 any pointing errors can be measured as the difference between the known and sensed bearings and any such pointing errors can then be corrected for. Alternatively, in order to ensure that there are no possible problems due to this retro reflector 18 being obscured, a separate reference retro reflector could be provided for each sensing and illumination unit 3 adjacent the respective unit 3. Alternatively each sensing and illuminating unit 3 could calibrate itself using a plurality of fixed reference reflectors spaced apart in the cockpit sequentially.

Although the system shown employs a sensing and illuminating unit in which the infra red transmitter 4 and tracker 5 are physically moved to track the retro reflectors 2 it would be possible to keep the transmitter and tracker fixed and use a moving mirror to track the retro reflectors.

The various data processing and storage tasks necessary to allow the system to operate are shown herein as being formed by a number of discrete elements, they could alternatively be carried out by a single appropriately programmed general purpose computer.

The infra red illuminators 4 could be modulated and

the associated sensor 5 set to react to this modulation in order to reduce the possibility of interference by external infra red sources, the illuminators 4 could also be uniquely modulated to prevent interference between the separate illuminators.

Although the system described above employs infra red radiation, radiation at other wavelengths could be used.

CLAIMS

1. A helmet position measurement system comprising three illuminating and sensing units mounted at fixed positions relative to an aircraft cockpit and three retro reflectors mounted at fixed positions on a helmet, each of the illuminating and sensing units being arranged to track a separate one of the retro reflectors by emitting light which is reflected from the retro reflector back to the unit and to supply data giving the bearing from each of the units to its respective retro reflector to a position and orientation calculating device which calculates the position and orientations of the helmet from this bearing data.

2. A system as claimed in claim 1 in which each illuminating and sensing unit has a field of view comprising only a part of the cockpit and moves this field of view to track its respective retro reflector.

3. A system as claimed in claim 2 in which each illuminating and sensing unit has a field of illumination comprising only a part of the cockpit

which is within its field of view.

4. A system as claimed in claim 3 in which the field of view and field of illumination of each illuminating and sensing unit are boresighted.

5. A system as claimed in any preceding claim in which the light is infra red radiation.

6. A system as claimed in any preceding claim in which more than three retro reflectors are mounted on the helmet, but each unit tracks only one retro reflector at a time.

7. A system substantially as shown in or as described with reference to figure 1 of the accompanying drawings.

8. A system substantially as shown in or as described with reference to figure 2 of the accompanying drawings.

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Patents Act 1977
Examiner's report to the Comptroller under Section 17 (The Search Report)

Search Examiner
T BERRY

Relevant Technical fields

(i) UK Cl (Edition L) H4D (DLPC, DLPX)

(ii) Int Cl (Edition 5) F41G, G01S

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25 MAY 1993

Databases (see over)

(i) UK Patent Office

(ii) Online Database: WPI

Documents considered relevant following a search in respect of claims 1 to 8

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
A	GB 2234877 A (GEC-MARCONI)	1
A	EP 0493651 A2 (HONEYWELL)	1
A	US 3867629 (US NAVY SEC.)	1

SF2(p)